《公平交易季刊》
第 22 卷第 3 期（103/07），頁 115-138
◎公平交易委員會

Spatial Competition in the Bottled Liquefied Petroleum Gas Wholesale Market in Taiwan

Kannika Saeliw*
Sun, Li-Chyun
Chang, Hung-Hao

Abstract

Why can different product prices exist for an industry consisting of many small firms with perfectly identical products? This paper provides a possible explanation of this phenomenon by underscoring the importance of the spatial competition on price determination using a survey data of bottled Liquefied Petroleum Gasfirms in Taiwan. A spatial lag model was estimated to empirically test whether spatial differentiation results in strategic interdependence in price determination among many small wholesalers after controlling for firm characteristics, cost and demand conditions.

We found evidence of pricing power from spatial differentiation in local wholesale markets even though the industry is highly competitive. Results showed a positive spatial interaction of firms' competition behaviors. Specification test showed that firms were more likely to engage in strategic interaction in pricing with nearby firms, especially

Date submitted: December 23, 2013 Date accepted:June 24, 2014

* Kannika Saeliw, Ph. D. Candidate, Department of Agricultural Economics, National Taiwan University. Sun, Li-Chyun, Associate Professor, Department of Agricultural Economics, National Taiwan University. Chang, Hung-Hao (Corresponding Author), Associate Professor, Department of Agricultural Economics, National Taiwan University.

with its four-closest rivals. Moreover, the variations in wholesale prices were driven by market conditions and spatial competition in local market rather than firms' marginal costs.

Keywords: Spatial Lag Model, Bottled Liquefied Petroleum Gas (LPG), Taiwan, Spatial Competition

1. Introduction

Conventional economic theory of perfect competitions predicts that an industry consisting of many small firms of perfectly identical products is mostly selling for one price. However, the one price situation is not always observed in the real world data. This paper provides a possible explanation of this phenomenon by underscoring the evidenceof the spatial competition in price determining using a surveillancedata of bottled Liquefied Petroleum Gas (LPG) firms in Taiwan. Bottled LPG is physically homogeneous product and commonly used for heating and cooking in Taiwan's residential market. However, not much attention had been paid on the competitions either in the wholesale markets or the retail markets in literature because both markets consists of numerous small firms and the selling prices are not determined by any dominant firms in each market.

Recently, the large gaps in prices of bottled LPG occur within and between cities/countries in Taiwan. This wide dispersion of prices can be easily observed and has aroused public concern. The difference between the maximum and minimum retail prices for a 20-kilogram canister of gas in the same cities/countries had a wide price range of NT$5 up to NT$260 per 20-kilogram canister where the price spread and the monthly average retail price was highest in Taipei city, the most densely populated city in Taiwan[1]. It is interesting that the variation in prices not only occurred in the retail market, but also appeared in the wholesale market. According to the survey data in 2009 the monthly average wholesale price of LPG had a spread from NT$3.65 to NT$3.85 per kilogram or NT$73 to NT$77 per 20-kilogram canister; the wholesale price was lowest in Ilan country and Kaohsiung city, whereas highest in Hualien country[2]. To understand the causes of volatility in bottled LPG retail price, it is interesting to investigate the competition in the

[1] Ministry of Economic Affairs (2009).

[2] Fair Trade Commission self-initiated investigation of bottled Liquefied petroleum gas industry (2010).

wholesale market. Because the retailers buy gas from the wholesalers and make profits from marking up the wholesale price, the retail prices might be highly influenced by the wholesale prices. With the price gaps in the wholesale market, it seems like the wholesalers might have some pricing powers over prices. However, according to the quantity sold of all wholesalers in 2009 both the four-firm concentration ratio (CR_4), showing that the total market share of the four largest firms was less than 10 percent and Herfindahl–Hirschman Index (HHI) of 0.01indicateda very low market concentration[3]. Therefore, it is interesting to investigate what causes the volatility of wholesale price exists in such less concentrated market.

The assumption of the competitive market theory commonly ignores the effect of spatial differentiation when price conscious consumers incur travel costs from buying a homogeneous product. However, if firms have pricing power, firms might have the potentials to engage in strategic interaction in pricing decisions from spatial differentiation[4]. With a growing research interest on spatial econometrics[5], some recent studies have applied spatial econometrics to under score the importance of the spatial competition in pricing decisions between firms. For example, Kalnins[6] used hamburger price data of 1,385 locations of the four largest fast-food chains in Texas to analyze the degrees of product and location substitution between franchised chains. The study noted that if hamburger prices of nearby stores of different chains were spatially correlated, consumers view their products as substitutes; Mobley[7]and Mobley et al.[8]tested California

---

[3] Calculated from survey data conducted by FTC (2009).

[4] P. F. Byrne, "Geographic Competition in the Retail Gasoline Market: Who Are a Gas Station's Competitors?" *36(2) Journal of Economics*, 75-97 (2010).

[5] Spatial econometrics identifying the interdependence among observations that are in close geographical proximity have been widely used in the field of health and epidemiology, hedonic house pricing model, and applied economics in agriculture, public economics, international trade, and many other fields.

[6] A. Kalnins, "Hamburger Prices and Spatial Econometrics," *12(4) Journal of Economics and Management Strategy*, 591-616 (2003).

[7] L. R. Mobley, "Estimating Hospital Market Pricing: An Equilibrium Approach Using Spatial Econometrics," *33(4) Regional Science and Urban Economics*, 489-516 (2003).

[8] L.R. Mobley, H. E. Frech, & Luc Anselin, "Spatial Interaction, Spatial Multipliers and Hospital Competition," *16(1) International Journal of the Economics of Business*, 1-17 (2009).

hospital pricingand estimated the effect of market concentration on hospital equilibrium prices; Byrne[9] investigated the strategic interactionin the pricing decision between the neighboring firms of 663 gasoline stations in the US by assuming the equilibrium prices were determined by each firm's characteristics, local demand determinants as well as the spatial interdependence among the competing firms. All studies pointed to the existence of spatial interaction in the pricing decision between firms, except for the one by Kalnins.

Although spatial competition has been applied to investigate the inter-firm pricing in less concentrated market, most of these studies focused on the industry selling a wide range of product or service types. Though gasoline and LPG is physically identical product, gasoline stations may compete not only on location, but also on quality, and many services such as convenience store, car wash and repair service[10,11]. Unlike gasoline, firms selling LPG might not maximize profits through product differentiation because such differentiation will cost more and might not be easily recognized by customers. Therefore, the primary source of firms' pricing powers from differentiated products might come from the physical locations rather than the product varieties. In addition, as there was a different price gap of bottled LPG in the different locations, we hypothesized that the competition in the bottled LPG wholesale market is localized. Therefore, the objective of this study was toempirically test whether location differentiation might create the possibility of strategic interdependence in bottled LPG pricing decisions between nearby wholesalers after controlling for firm characteristics, cost and demand conditions. Using data from a survey of bottled LPG industry conducted by FTC in 2009, the results showed the evidence of a positive spatial interaction in price setting among geographically close firms. In particular, each wholesaler considered conjectures ofits four nearest firms when making pricing decision.

The rest of the paper is organized as follows. Section 2 presents summary data of

---

[9] P. F. Byrne, *Supra* note 4.

[10] D. S. Hosken, S. M. Robert and Christopher T. Taylor, "Retail Gasoline Pricing: What Do WeKnow?" *26(6) International Journal of Industrial Organization*, 1425-1436 (2008).

[11] Dieter. Pennerstorfer, "Spatial Price Competition in Retail Gasoline Markets: Evidence from Austria," *43(1) Annals of Regional Science*, 133-158 (2009).

prices and definitions of variables. Section 3 reviews the analytical framework for LPG pricing. Empirical results, conclusions and policy implication are found in section 4 and 5, respectively.

2. Data

Data used in this research came from different sources. Data of the wholesale prices and the quantity sold from July to December in 2009 were drawn from survey conducted by FTC. The dependent variable is the monthly wholesale price of each firm which is defined as the average price of the minimum and maximum selling prices. We used thelatitude and longitude coordinates of each firm created from Google map based on the geographical addresses of the distributors and wholesalers drawn from Bureau of Energy in 2009 to calculate the Euclidean distances among firms using R statistical software[12]. The distances between the wholesalers were used to identify firms'competitors, whereas the average distance between the wholesalers and their distributors was used as a proxy for different marginal costs due to the differences in transportation costs[13]. Mobley et al.[14] found the impact of the market concentration on firms' pricing decisions under spatial differentiation. Following the similar strategy as used in Mobley et al., we used the Herfindahl-Hirschman index (HHI) to identify the market concentration for each local market. HHI was calculated by summing the squaring of the quantity sold or market share of each firm competing in the same city/country. Data of other demand determinants which is in line with the findings of previous empirical studies[15,16,17]of spatial

---

[12] R. Bivand, "Spdep: Spatial Dependence: Weighting Schemes, Statistics and Model," R package version *0.5-35* (2001).

[13] P. F. Byrne, *supra* note 4, 75-97.

[14] Mobley et al., *supra* note 8, 1-17.

[15] J. M. Barron, Beck A. T, and John R. U, "A Theory of Quality-Related Differences in Retail Margins: Why There is a 'Premium' on Premium Gasoline," *38(4) Economic Inquiry*, 550-569 (2000).

[16] P. F. Byrne, *supra* note 4, 75-97.

[17] D. S. Hosken, S. M. Robert and Christopher T. Taylor, *Supra* note 10.

price competiton were drawn from Bureau of Energy[18], Directorate General of Budget Accounting and Statistics[19]and Ministry of the Interior[20]. The number of retailers in each city, land area of each city as well asthe characteristics of the census tract such as population and mean household income of the city in which the firm is located were used to control for demand characteristics in the local area. In order to represent each firm's characteristics, the maximum quantity sold from July to December in 2009 was used as a proxy for firm's capacity. Sample statistics of the dependent variable and all explanatory variables are presented in Table 1.

3. The Analytical Framework

As retailers might prefer to buy a physically homogeneous gas from closest wholesalers in order to save their transportation costs, bottled LPG wholesalers might be more likely to compete in spatial differentiation rather than other type of product differentiation. Therefore, we assumed that competition in the bottled LPG wholesale market is localized, so that each wholesaler in the local market recognizes only their nearest firms as the most relevant competitors. Therefore, each local market can be characterized as oligopoly even though there are numerous wholesalers in the industry[21]. To model such oligopolistic interdependencies in the pricing decisions this study used the theorethical model proposed by Mobley in 2003. Mobley uses the standard oligopoly bertrand competition model to derive the firm price-reaction functions, and then applies a spatial lag model to estimate spatial price competition among many firms by specifying each firm's relevant competitors based on geographic proximity. The abbreviated model are described below[22].

---

[18] Ministry of Economic Affairs (2009).
[19] Directorate General of Budget Accounting and Statistics (2009).
[20] Ministry of the Interior (2009).
[21] Dieter. Pennerstorfer, *Supra* note 11.
[22] L.R. Mobley, *Supra* note 7.

Table 1 Variables definitions and sample statistics of the variables

Variable Name	Description	N	Mean	SD
Dependent variables:				
July Price	Average LPG wholesale price in July,2009 (NT$/kg)	56	23.14	1.17
August Price	Average LPG wholesale price in August,2009 (NT$/kg)	56	23.17	1.15
September Price	Average LPG wholesale price in September,2009 (NT$/kg)	56	24.57	1.25
October Price	Average LPG wholesale price in October,2009 (NT$/kg)	56	24.65	1.16
November Price	Average LPG wholesale price in November, 2009 (NT$/kg)	56	26.55	1.31
December Price	Average LPG wholesale price in December, 2009 (NT$/kg)	56	26.68	1.15
Independent Variables:				
Distance	Average Euclidean distance between the firm and its LPG distributors (100 km)	56	0.95	0.76
Capacity	Maximum LPG sold during the survey periods (100,000 kg/ month)	56	9.63	7.07
Area	Land area of a city in which the firm is located (100 km^2)	56	20.91	12.40
HHI	Herfindahl index of LPG sold in the city in which the firm is located	56	0.28	0.24
Population	Population of a city in which the firm is located (in 100,000 people)	56	13.02	10.84
Income	Average household income of a cityin which the firm is located (in NT$ 100,000 per year)	56	9.75	1.83
Retailer	Number of retailers in a citywhere the wholesaler is located (10 firms)	56	18.61	9.63

Source: Bureau of Energy 2009, Directorate General of Budget Accounting and Statistics,Fair trade Commission, and Ministry of the Interior

According to classical Bertrand model, Mobley assumes that firms choose price to maximize profits by holding conjectures about how rivals will react to their price changes and incorporating these conjectures into their decisions. The first-order condition of profit maximization is used to derived the firm's price reaction function or the best response function. So, each firm's profit maximizing price depends on both its characteristics and market conditions as well as conjecture about prices set by its competitors. Each firm's reaction function can be representedin the matrix notation as follows:

$$P^* = R(P; \Phi; Z; \delta) \tag{1}$$

Where P is price, δ is cost parameter, Z is demand condition and Φ is firm conjecture regarding other firms' prices.

When all firms simultaneously optimize profits, their price reaction functions associated with the conjecture will simultaneously determine the Nash equilibrium prices. As it is not easily to model the strategic interaction among numerous firms competing in a local market, Mobley derived the spatial lag framework developed by Brueckner[23]to model such interaction by using a set of spatial weights to characterize the interdependencies among firms. Mobley posits that the spatial lag model allows for spatial interaction among neighboring firms, and the spatial lag parameter is an estimate of the slope of the price-response curve. Nash equilibrium prices for numerous firms can be estimated by rewriting equation (1) into a linear form as:

$$P_i = \rho \sum_{j \neq i} w_{ij} P_j + X_i \beta + \varepsilon_i \tag{2}$$

Where w_{ij} represents the set of weights of spatial market that expresses the firm's direct competitors; $w_{ij} > 0$ if firm *i* considers firm *j* as its competitor, otherwise $w_{ij} = 0$. ε_i is i.i.d. random error terms. The weight matrix is then normalized to a row standardized weight style in order to get the elements of each row sum to one. So that $\sum_{j \neq i} w_{ij} P_j$ is

[23] Brueckner, Jan K.,"Testing for Strategic Interaction among Local Governments: The Case of Growth Controls,"*44(3) Journal of Urban Economics*, 438-467 (1998).

spatially weighted average of competitors' prices, which has a coefficient ρ. This coefficient is the slope of the reaction function[24] that explains a change in a firm's best response corresponding to one unit change in the average competing prices. Therefore, $\rho\sum_{j\neq i} w_{ij}P_j$ states a firm's response to a one unit change in the weighted average price of its competitors.

Equation (2) can also be written in matrix notation as follows[25]:

$$P = \rho WP + X\beta + \varepsilon \tag{3}$$

Taking expectation of the reduced form of equation (3):

$$E(P) = (I - \rho w)^{-1} X\beta \tag{4}$$

Where I is the identity matrix; the term of matrix inverse $(I-\rho w)^{-1}$ is the spatial multiplier with an infinite series as[26] $I + \rho w + \rho^2 w^2 + \rho^3 w^3 + \ldots$. When weights matrix is normalized to a row standardized weight style, the spatial multiplier equals to 1/(1- ρ)[27].

Substitute with the expansion of the spatial multiplier, equation (4) can be rewritten as follows:

$$E[P \mid X] = X\beta + \rho wX\beta + \rho^2 w^2 X\beta + \rho^3 w^3 X\beta + \ldots \tag{5}$$

where powers to the weights matrix (w , w^2 , w^3 , etc.) represent the competitors' orders. i.e., the first order is nearby competitors, the second-order competitors is the closest competitors of firm's nearby competitors, third-order is one's nearby competitors' nearby competitors' nearby competitors, and so forth.

Without strategic interaction in pricing decisions among firms $(\rho = 0)$, the empirical model of N-firms can be reduced to $X\beta + \varepsilon$. As a result, there is only the direct effect from a change in firms' characteristics on equilibrium price. However, if there is any

---

24 Mobley (2003) stated that if products are substitute, the slope of the reaction function is positive.

25 P is an $n \times 1$ vector of the firm's profit-maximizing price; X is an $n \times k$ matrix of firm's characteristics and market demand condition; ρ is an $k \times 1$ vector of regression coefficients; W is an $n \times n$ spatial weights matrix; ε is an $n \times 1$ vector of random.

26 J. P. LeSage & R. K. Pace, *Introduction to Spatial Econometrics* (2009).

27 L. Anselin, "Spatial Externalities, Spatial Multipliers, and Spatial Econometrics," *26(2) International Regional Science Review*, 153-166 (2003).

interaction among firms, spatial lag model indicates that a change in firm's characteristic not only affects its own price, but also impacts the pricing decisions of all other competing firms *j* and eventually return to influence its price, and so on through the spatial multiplier mechanism[28,29]. From equation (5), the powers of rho matcing the powers of weights matrix indicate that one wholesaler's price can influence all other firms in the sample, even those who are not defined as its direct competitors. The influences of higher order neighbors decline with the order of competitors as $|\rho| < 1$[30]. Therefore, the spill over effect of a change in one firm's characteristic on equilibrium price eventually magnifies the direct effect of the coefficient estimates of firms' characteristics by the magnitude of the spatial lag coefficient through the spatial multiplier process[31].

This study used the spatial lag model to determine whether Bottled LPG wholesale market in Taiwan is localized. If there is no spatial competition in the wholesale market, consumers or retailers do not view wholesalers' products as substitutes. In this case, we should observe each wholesaler sets price independently of the others. More specifically, the presence of any low or high price of a particular wholesale will not influence other wholesalers to increase or decrease their selling prices. To investigate any change in demand or cost condition of one particular wholesaler by using the ordinary least square (OLS), which is ignored the spatial interaction, will give the same result as using the spatial lag model. In contrast, if there is any spatial competition in the wholesale market, retailers may view their products as substitutes. Therefore, wholesalers will maximize their profits by setting prices associated with their rivals' prices. As a result, we should observe each wholesaler's selling price to be partly influenced by their neighbors. As strategic interaction in pricing decisions will magnify the effect of any change in one particular wholesaler's characteristic through spill over effect, using OLS rather than the

[28] J.D. Morenoff, "Neighborhood Mechanisms and the Spatial Dynamics of Birth Weight," 108(5) American Journal of Sociology, 976-1017 (2003).

[29] M.D. Ward & S.G. Kristian, Spatial Regression Models, Los Angeles: Sage Publications (2008).

[30] Byrne, *supra* note 4, 75-97.

[31] J.D. Morenoff, *Supra* note 28.

spatial lag model should provide the bias results of the effects of changing in firms' characteristics.

3.1 The Weights Matrices of Firm's Competitors

We used geographic distances among firms to specify a set of closest or direct competitors of each firm in the form of a spatial weights matrix. As different definitions of spatial dependence will have different neighboring structure, many studies[32,33,34] commonly use either distance-based weighting method or k nearest neighbor (KN) or both to specify neighboring structure. This study applies three weighting criteria to define spatial competing firms: k-order nearest neighbor, inverse distance and inverse distance squared.

For k- nearest competitors criterion, each firm has exactly "k" competitors; firms place an equal weight on their all k-nearest competitors' pricing decisions and a zero weight on otherwise. In this study, an order is assigned from 3 to 12; each k- nearest neighbor set is used to construct a spatial weights matrix. For inverse distance and inverse distance squared approach, all firms j are identified as competitors of focal observation *i* if their distances (d) less than a specified distance threshold ($\bar{d}$) of 45 kilometers up to 120 kilometers in order to ensure that all firms have at least one neighbor; then each spatial weights matrix of these schemes has a weight with a function of their inverse distance or inverse distance squared, i.e. elements w_{ii} on the main diagonal equal zero whereas elements $w_{ij}= d^{-1}$ *or* $w_{ij}= d^{-2}$ if $w_{ij}<\bar{d}$,and $w_{ij}= 0$ if $w_{ij}>\bar{d}$.

---

32 R. Basile, "Productivity Polarization across Regions in Europe," *32(1) International Regional Science Review*, 92-115 (2009).

33 D. R. Chen & T. H. Wen, "Elucidating the Changing Socio-Spatial Dynamics of Neighborhood Effects on Adult Obesity Risk in Taiwan from 2001 to 2005," *16(6) Health Place*, 1248-1258 (2010).

34 L. Osland, "An Application of Spatial Econometrics in Relation to Hedonic House Price Modeling," *32(3) Journal of Real Estate Research*, 289-320 (2010).

4. Empirical Results

4.1 Testing for Spatial Effects

All models were estimated by R software package *spdep*. This study used Moran's I statistic to test whether there was any spatial dependence for each spatial weights matrix[35]. Then, Lagrange Multiplier diagnostics for spatial dependence was used to test whether spatial lag model was appropiated than spatial error model for those weights matrices[36,37,38]. As the spatial multiplier effect is due to the specification of a set of competing firms, this study used the AIC value to find the most suitability set of weights matix. The model with the lowest AIC value is the optimal model, and therefore will be discussed.

Results of Moran's I and Lagrange Multiplier testing for all weighting schemes showed that most of spatial weights matrices provided the incidence of spatial autocorrelation in firms' pricing models and the appropriateness of using a spatial lag model. The AIC value of a model using the four-closest competitor specification of spatial weights exhibited the best fit. In addition, Lagrange Multiplier (LM) test for residual autocorrelation and Breusch-Pagan (BP) test also showed that this model had no more spatial autocorrelation in the data and no more heteroskedasticity in the residuals (see Table A1).

4.2 The Spatial Interaction in LPG Pricing and Demand Determinants

---

[35] L. Anselin, Spatial Regression Analysis in R: A Workbook,Urbana-Champaign: Universityof Illinois (2005b).

[36] L. Anselin,"Lagrange Multiplier Test Diagnostics for Spatial Dependence and Spatial Heterogenity," 20 Geographical Analysis, 1-17 (1988).

[37] L. Anselin, *Exploring Spatial Data with GeoDa: A Workbook*, http://www.csiss.org, last visited on date: 2013/12/20 (2005).

[38] L. Anselin & A. K. Bera, "Simple Diagnostic Tests for Spatial Dependence," *Regional Science & Urban Economics*, 26, 77(1996).

Though the entire discussion will be limited to the model using k=4 weights matrix, Table 2 shows both the estimated results of least-squares model with no accounting for spatial interaction and the spatial lag models using the k=3, k=4, and k=5 weighting matrices. The significances of estimated ρ supported the theory of spatial interaction in pricing and indicated that least-squares estimate is biased and inconsistent. Furthermore, the interaction coefficients were qualitatively insensitive to the neighboring structures. The coefficients of independent variables didnot dramatically change whena set of rivals varies from four nearest competitors. The statistical significances of coefficients from three spatial lag models were similar in sign and magnitude. Table 3 also exhibits the existence of spatial interaction in pricing throughout the survey period.

For the four-closest neighbor model, the strategic interaction coefficient of 0.62 resulting in a spatial multiplier of 2.61. In general, the coefficients on most of the explanatory variables were statistically significant and had the expected sign. Taking the result in wholesale prices of bottled LPG on December, 2009 for instance, the estimated coefficient of market concentration (HHI) was positively significant and was in line with finding of the previous research that greater market concentration is associated with greater power of firms to influence prices[39]. The coefficient of HHI was 1.40 indicating a unit increase in market concentration had a direct impact of NT$ 1.40 increase in the price of one kilogram LPG or NT$ 28 increase per 20-kilogram canister. However, strategic interaction in pricing among firms caused nearby firms responding to the price increase in the initial firm's best response function by raising their prices, which in turn affected the initial firm who response with further price increase until the new equilibrium was reached. The ripple effect of spatial multiplier eventually increased LPG price by NT$ 3.67 per one kilogram of LPG or NT$73.4 per 20-kilogram canister (=3.67x20 kg). Almost 60 percent of the impact of market concentration on euilibrium price was the effect from strategic interaction in pricing among firms.

The coefficient of population was positive and significant indicating that an increase

---

[39] *Supra* note 8.

Table 2 Empirical results

Variable	OLS	Spatial Lag Model (SLM) : K-order nearest		
		K=3	K=4	K=5
(Intercept)	22.63 ***	9.89 ***	8.63 ***	6.37 ***
	(1.45)	(2.33)	(2.35)	(2.22)
Distance	0.02	0.06	0.07	0.09
	(0.17)	(0.13)	(0.13)	(0.13)
HHI	1.69 *	1.11 *	1.40 **	1.71 ***
	(0.81)	(0.59)	(0.58)	(0.59)
Area	0.06 ***	0.03 ***	0.03 ***	0.04 ***
	(0.01)	(0.01)	(0.01)	(0.01)
Population	0.05	0.04 *	0.04 *	0.04 *
	(0.03)	(0.02)	(0.02)	(0.02)
Income	-0.08	-0.07	-0.08	-0.06
	(0.12)	(0.08)	(0.08)	(0.08)
Retailer	-0.07 *	-0.05 **	-0.04 **	-0.04 *
	(0.03)	(0.02)	(0.02)	(0.02)
Capacity	0.02	0.02	0.02 *	0.03 *
	(0.02)	(0.01)	(0.01)	(0.01)
R-squared	0.47			
F-statistic	6.11 ***			
Rho		0.57 ***	0.62 ***	0.70 ***
Log likelihood		-58.56	-57.57	-59.03
LM test-spatial error		0.81	0.06	0.00
BP		5.35	5.40	5.37
AIC	157.56	137.13	135.15	138.06
Global Multiplier		2.32	2.61	3.32
Total Effect				
HHI		2.57	3.67	5.67
Area		0.07	0.08	0.12
Population		0.08	0.09	0.12
Retailer		-0.11	-0.10	-0.13
Capacity		0.05	0.07	0.09

Note: Total effect is the multiplication of the direct impact of the coefficient by the spatial multiplier Standard deviations in parentheses ***, **, * are the significance at 1%, 5%, and 10% level, respectively

Source: Estimated by the authors

Table 3 Empirical results, August 2009-December 2009

Variable	Spatial Lag Model (SLM) : K-order nearest = 4				
	AUG	SEP	OCT	NOV	DEC
(Intercept)	9.18 ***	11.13 ***	9.75 ***	12.12 ***	10.35 ***
	(2.34)	(2.80)	(2.49)	(3.11)	(2.64)
Distance	-0.02	0.01	0.01	0.00	-0.02
	(0.12)	(0.15)	(0.12)	(0.16)	(0.12)
HHI	1.26 **	1.24 *	1.30 **	1.21	1.15 **
	(0.56)	(0.68)	(0.57)	(0.74)	(0.57)
Area	0.03 ***	0.04 ***	0.03 ***	0.03 **	0.03 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Population	0.04 **	0.05 **	0.04 *	0.05 *	0.04 *
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Income	-0.08	-0.09	-0.07	-0.09	-0.08
	(0.08)	(0.10)	(0.08)	(0.11)	(0.08)
Retailer	-0.05 **	-0.05 **	-0.05 **	-0.06 **	-0.04 **
	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)
Capacity	0.02 *	0.03 *	0.02 *	0.03	0.02
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
Rho	0.61	0.55	0.60	0.55	0.62
Log likelihood	-55.24	-65.40	-56.41	-70.78	-56.26
LM test-spatial error	0.01	0.41	0.04	0.32	0.02
BP	3.55	2.86	3.06	2.78	3.27
AIC	130.47	150.80	132.82	161.57	132.52
AIC(OLS)	153.29	166.43	153.99	176.25	155.76
Global Multiplier	2.54	2.20	2.47	2.21	2.60
Full Effect					
HHI	3.20	2.73	3.22	2.68	3.00
Area	0.07	0.08	0.08	0.07	0.07
Population	0.10	0.11	0.09	0.11	0.10
Retailer	-0.12	-0.12	-0.11	-0.13	-0.12
Capacity	0.06	0.06	0.06	0.06	0.06

Note: Standard deviations in parentheses. ***, **, * are the significance at 1%, 5%, and 10% level, respectively

Source: Estimated by the authors

of 100,000 people resulted in a marginal effect of NT$0.8 increase in the price for a 20-kilogram canister and a corresponding total effect of NT$1.80 per 20-kilogram canister. Because LPG is normal good, increase in end users should increase the demand for bottled LPG. The negative impact of land area of a city in which the firm is located indicated that increase area of 100km^2 resulted in total effect of price NT$1.6 increase for a 20-kilogram canister. Numbers of retailers had a negative impact on market prices. When a number of retailers increase, one wholesaler may reduce its price to get more customers. As bottled LPG is homogeneous, other firms may be forced to lower their prices. The interaction in pricing decisions may lead more price cuts and low market prices. For example, more ten retailers had a direct effect of NT$ 0.80 decrease in the price for a 20-kilogram canister and eventually decreased the market price by NT$2 per 20 kilogram canister. The finding that the increasing capacity increased the pricing power of wholesalers was consistent with the expectation. Firm with larger capacity is more likely to be a dominant firm in the local market and therefore has more pricing power. Finally, he average household income of end user and average distance between firm and its suppliers, which proxy for marginal cost differences, were not significant[40].

Due to the significant coefficients of market concentration and some demand determinants coupled with lack of significance of marginal cost, we concluded that market wholesale prices were driven by market condition and spatial competition rather than firm marginal costs.

5. Conclusions and Policy Implications

This study applied the spatial lag modelto examine the price competition of the bottled LPG wholesale market in Taiwan. Results showed that the wholesale prices

[40] We also used the average buying cost from firm's distributors and the minimum distance between firm and its distributors as proxy variables for firm's marginal cost. We got the similar estimation results as those obtained from using average distance as a proxy for cost difference due to transport cost.

might be spatially correlated. We found evidence for pricing powers from spatial differentiation in local wholesale markets even though the industry is highly competitive. However, the large spatial lag coefficient indicated that products were not perfect substitutes, but close substitutes for at least some customers. Given firm's pricing power, firms engaged in strategic interaction in pricing decision with their four closest competitors. We also found that variations in wholesale prices were driven by market conditions and spatial competition in local market rather than firm marginal costs. In addition, almost two-thirds of a change in market equilibrium price associated with changes in demand conditions or firm's characteristics changes is the indirect effect of strategic interaction.

Some policy implications can be inferred from our findings. It is necessary to prevent mergers or collusions between competing firms because an increase in market power from mergers might result in substantial increase in price through spatial multiplier process. Suppose market concentration increase from the mean for our sample to perfect collusion that all firms in the local market acting as a single monopolist. The market prices will increase almost 10 percent. With strategic interaction, the competitive harm is greater because the price effect extends outside of the local market through spillover effect. This price increase from collusions may also affect the variation in retail price because the wholesale price accounts almost 60% of the retail price[41]. On the other hand, the competitive forces in local market may cause any policy to be more effective though the ripple effect from price cut. If we can reduce the market concentration, the market price will be decreased. Then the retailers and households will earn more benefits.

[41] Calculated from the wholesale price from survey data conducted by Fair Trade Commission and the retail price announced by Bureau of Energy.

Appendix 1

Table A1 Diagnostic tests for all weighting schemes

	Rho	Log-likelihood	AIC	LM test[1/]	BP[2/]
k-order nearest					
k=3	0.57***	-58.56	137.13	0.81	5.35
k=4	0.62***	-57.57	135.15	0.06	5.40
k=5	0.70***	-59.03	138.06	0.00	5.37
k=6	0.73***	-59.82	139.63	0.09	5.70
k=7	0.75***	-60.44	140.88	0.78	5.99
k=8	0.75***	-61.46	142.92	0.92	6.33
k=9	0.74***	-62.47	144.95	0.23	6.47
k=10	0.75***	-63.07	146.14	0.73	7.13
k=11	0.73***	-63.98	147.96	0.57	7.25
k=12	0.76***	-64.06	148.12	0.77	7.21
Inverse distance: w=I/d					
d=45 km	0.57***	-58.29	136.59	4.10**	5.93
d=50 km	0.59***	-58.09	136.18	4.05**	6.10
d=55 km	0.59***	-58.18	136.36	3.95**	6.28
d=60 km	0.63***	-57.60	135.20	3.18*	6.01
d=65 km	0.64***	-57.73	135.47	2.29	5.86
d=70 km	0.63***	-58.60	137.21	1.24	5.86
d=75 km	0.63***	-58.62	137.25	1.15	5.87
d=80 km	0.64***	-58.87	137.74	1.03	5.82
d=85 km	0.64***	-59.11	138.23	1.03	5.69
d=90 km	0.64***	-59.98	139.95	0.54	5.83
d=95 km	0.62***	-61.12	142.24	0.56	6.28
d=100 km	0.61***	-61.98	143.97	0.50	6.44
d=105 km	0.59***	-63.00	146.01	0.27	6.69
d=110 km	0.57***	-63.51	147.02	0.17	6.91
d=115 km	0.57***	-63.73	147.47	0.13	7.04
d=120 km	0.58***	-63.71	147.43	0.07	7.03
Inverse distance square: $w=I/d^2$					
d=45 km	0.49***	-60.43	140.86	5.83**	5.73
d=50 km	0.49***	-60.36	140.73	6.01**	5.82

Table A1 Diagnostic tests for all weighting schemes (continued)

	Rho	Log-likelihood	AIC	LM test[1/]	BP[2/]
d=55 km	0.50***	-60.36	140.72	5.99**	5.89
d=60 km	0.51***	-60.17	140.35	5.81**	5.72
d=65 km	0.51***	-60.23	140.46	5.28**	5.67
d=70 km	0.51***	-60.58	141.17	4.16**	5.70
d=75 km	0.51***	-60.62	141.24	4.02**	5.69
d=80 km	0.50***	-60.70	141.39	3.81*	5.70
d=85 km	0.50***	-60.77	141.54	3.87**	5.68
d=90 km	0.50***	-61.15	142.30	3.29	5.79
d=95 km	0.49***	-61.70	143.40	3.12*	5.97
d=100 km	0.48***	-61.90	143.79	3.03*	6.02
d=105 km	0.48***	-62.28	144.57	2.75*	6.11
d=110 km	0.47***	-62.43	144.85	2.58	6.17
d=115 km	0.47***	-62.50	145.00	2.51	6.19
d=120 km	0.47***	-62.48	144.95	2.49	6.17

Note:

For k nearest neighbors: all weights matrices have spatial autocorrelation in prices, but only k=3-5 show the appropriateness of using a spatial lag model.

For distance based: all weighs matrices provide the incidence of spatial autocorrelation in firms' pricing models and the appropriateness of using a spatial lag model.

1/ LM test for residual autocorrelation

2/Breusch-Pagan test on heteroskedasticity in the residuals

Source: Estimated by the authors

References

Anselin, L., "Lagrange Multiplier Test Diagnostics for Spatial Dependence and Spatial Heterogeneity," _20 Geographical Analysis_ (1988).

Anselin, L., "Spatial Externalities, Spatial Multipliers, and Spatial Econometrics," _26(2) International Regional Science Review_ (2003).

Anselin, L., _Exploring Spatial Data with GeoDa: A Workbook_, Spatial Analysis Laboratory,Department of Geography, University of Illinois, Urbana-Champaign, Urbana, IL (2005).

Anselin, L., _Spatial Regression Analysis in R: A Workbook_, Urbana-Champaign: Universityof Illinois (2005b).

Anselin, L. & Bera, A. K., "Simple Diagnostic Tests for Spatial Dependence," _26 Regional Science & Urban Economics_ (1996).

Barron, J. M., Beck, A. T. & John, R. U., "A Theory of Quality-Related Differences in Retail Margins: Why There is a 'Premium' on Premium Gasoline," _38(4) Economic Inquiry_ (2000).

Basile, R., "Productivity Polarization across Regions in Europe," _32(1) International Regional Science Review_ (2009).

Bivand, R., "Spdep: Spatial Dependence: Weighting Schemes, Statistics and Models," _R package version 0.5-35_ (2001).

Brueckner, Jan K., "Testing for Strategic Interaction among Local Governments: The Case of Growth Controls," _44(3) Journal of Urban Economics_ (1998).

Byrne, Paul F., "Geographic Competition in the Retail Gasoline Market: Who Are a Gas Station's Competitors ?" _36(2) Journal of Economics_ (2010).

Chen, D. R. & Wen, T. H., "Elucidating the Changing Socio-Spatial Dynamics of Neighborhood Effects on Adult Obesity Risk in Taiwan from 2001 to 2005," _16(6) Health Place_ (2010).

Hosken, D. S., Robert, S. M. & Taylor, Christopher T., "Retail Gasoline Pricing: What Do We Know?" *26(6) International Journal of Industrial Organization* (2008).

Kalnins, A., "Hamburger Prices and Spatial Econometrics," *12(4) Journal of Economics and Management Strategy* (2003).

LeSage, J. P. & Pace, R. K., *Introduction to Spatial Econometrics* (2009).

Mobley, Lee R., "Estimating Hospital Market Pricing: An Equilibrium Approach Using Spatial Econometrics," *33(4) Regional Science and Urban Economics* (2003).

Mobley, Lee R., Frech, H. E. and Anselin, Luc, "Spatial Interaction, Spatial Multipliers and Hospital Competition," *16(1) International Journal of the Economics of Business* (2009).

Morenoff, J.D., "Neighborhood Mechanisms and the Spatial Dynamics of Birth Weight," *108(5) American Journal of Sociology* (2003).

Osland, L., "An Application of Spatial Econometrics in Relation to Hedonic House Price Modeling," *32(3) Journal of Real Estate Research* (2010).

Pennerstorfer, Dieter., "Spatial Price Competition in Retail Gasoline Markets: Evidence from Austria," *43(1) Annals of Regional Science* (2009).

R. Development Core Team, *R: A Language and Environment for Statistical Computing,* R Foundation for Statistical Computing, Vienna, Austria (2013).

Ward, M.D. & Kristian S.G., *Spatial Regression Models*, Los Angeles: Sage Publications (2008).

臺灣桶裝瓦斯批發市場的空間競爭

劉永潔*
孫立群
張宏浩

摘要

一個產業中若存在許多生產相同產品的小廠商時，為何會有不同銷售價格存在？本文以臺灣桶裝液態石油氣（LPG）零售為例，說明造成此原因在於空間區位競爭之結果。在不考慮成本及需求的變動之下，本文採用空間落遲計量模型來檢定桶裝瓦斯分裝廠在地區差異化下彼此間價格策略的關聯性。

即使產業競爭激烈，我們從當地分裝廠市場的地區差異結果發現訂價能力的證據。廠商的競爭行為具有正向的空間相互作用。模型檢定結果顯示，廠商較可能與鄰近廠商進行訂價策略相互作用，特別在與鄰近四家廠商間，此原因造成價格上的差異。此外，在分裝廠的價格變動主要來自市場情況和當地市場地區競爭驅動所致，而非來自廠商邊際成本的差異。

關鍵詞：空間落遲模型、桶裝液態石油氣、液態石油氣、臺灣、空間競爭

投稿日期：102 年 12 月 23 日　　　　審查通過日期：103 年 6 月 24 日

* 劉永潔係國立臺灣大學農業經濟學系博士候選人；孫立群係國立臺灣大學農業經濟學系兼任副教授；張宏浩（通訊作者）係國立臺灣大學農業經濟學系副教授。